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Patentanmeldung Nr. | Patent application No. | Demande de brevet n°

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Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
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Blatt 2 der Bescheinigung
Sheet 2 of the certificate
Page 2 de l'attestation

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Background gas composition for use in lithographic projection apparatus

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Background Gas Composition for use in Lithographic Projection Apparatus

The invention relates to a background gas composition for use in lithographic projection apparatus comprising:

an illumination system for supplying a projection beam of electromagnetic radiation;

a first object table for holding a mask;

a second object table for holding a substrate; and

a projection system for imaging an irradiated portion of said mask onto a target portion of said substrate.

For the sake of simplicity, the projection system may hereinafter be referred to as the "lens"; however, this term should be broadly interpreted as encompassing various types of projection system, including refractive optics, reflective optics, and catadioptric systems, for example. The radiation system may also include elements operating according to any of these principles for directing, shaping or controlling the projection beam, and such elements may also be referred to below, collectively or singularly, as a "lens". In addition, the first and second object tables may be referred to as the "mask table" and the "substrate table", respectively. Further, the lithographic apparatus may be of a type having two or more mask tables and/or two or more substrate tables. In such "multiple stage" devices the additional tables may be used in parallel, or preparatory steps may be carried out on one or more tables while one or more other tables are being used for exposures.

Lithographic projection apparatus can be used, for example, in the manufacture of integrated circuits (ICs). In such a case, the mask (reticle) may contain a circuit pattern corresponding to an individual layer of the IC, and this pattern can be imaged onto an exposure or target area (containing one or more dies) on a substrate (silicon wafer) which has been coated with a layer of radiation-sensitive material (resist). In general, a single wafer will contain a whole network of adjacent target areas which are successively irradiated via the mask, one at a time. In one type of lithographic projection apparatus, each target area is irradiated by exposing the entire mask pattern onto the target area in one go; such an

apparatus is commonly referred to as a wafer stepper. In an alternative apparatus — which is commonly referred to as a step-and-scan apparatus — each target area is irradiated by progressively scanning the mask pattern under the projection beam in a given reference direction (the "scanning" direction) while synchronously scanning the substrate table parallel or anti-parallel to this direction; since, in general, the projection system will have a magnification factor M (generally < 1), the speed V at which the substrate table is scanned will be a factor M times that at which the mask table is scanned. More information with regard to lithographic devices as here described can be gleaned from International Patent Application WO97/33205, for example.

In general, lithographic apparatus contain a single mask table and a single substrate table. However, machines are becoming available in which there are at least two independently moveable substrate tables; see, for example, the multi-stage apparatus described in International Patent Applications WO98/28665 and WO98/40791. The basic operating principle behind such multi-stage apparatus is that, while a first substrate table is at the exposure position underneath the projection system for exposure of a first substrate located on that table, a second substrate table can run to a loading position, discharge a previously exposed substrate, pick up a new substrate, perform some initial measurements on the new substrate and then stand ready to transfer the new substrate to the exposure position underneath the projection system as soon as exposure of the first substrate is completed; the cycle then repeats. In this manner it is possible to increase substantially the machine throughput, which in turn improves the cost of ownership of the machine. It should be understood that the same principle could be used with just one substrate table which is moved between exposure and measurement positions.

In the case of the current invention, the projection system will generally consist of an array of mirrors, and the mask will be reflective; see, for example, the apparatus discussed in WO 99/57596 (P-0111). The radiation in this case is preferably electromagnetic radiation in the extreme ultraviolet (EUV) range, and possible sources include synchrotron radiation from electron storage rings, laser-produced plasma sources, for example those described in US Patent Application No. 09/466,217 (P-0162) and discharge plasma sources, for example those described in European Patent Application No. 00202304.2 (P-0191).

An example of an illuminator comprised in the illumination system and suitable for use with such radiation is described in European Patent Application no 98204237.6 (P-

0122), whereas a suitable condenser for use with EUV is described in European Patent Application no 00300784.6 (P-0129).

It is well known that contaminant particles, such as hydrocarbon molecules and water vapor, are present in lithographic projection apparatus. These contaminant particles may include the debris and by-products that are sputtered loose from the substrate, for example by an EUV radiation beam. Since parts of lithographic projection apparatus, such as the illumination system and the projection system, are generally at least partially evacuated, these contaminant particles tend to migrate to such areas. The particles then adsorb to the surfaces of the optical components located in these areas. This contamination of the optical components causes a loss of reflectivity, which may adversely affect the accuracy and efficiency of the apparatus, and may also degrade the components' surfaces, thus reducing their useful lifetime.

Previous methods which have been proposed to remove impurities from the apparatus have involved suppressing the movement towards the projection system of debris produced by the sputtering of the surface of the substrate. For example, it has previously been suggested that the problem can be addressed by increasing the distance between the substrate and the final optical component, by introducing a "gas curtain" between the substrate and the final optical component to sweep away the debris. Such methods are directed to preventing contaminants from entering, for instance, the projection system. However, some contaminants may still enter the system or may be generated in the system itself, e.g. by moving parts.

It is an object of the invention to provide a method of suppressing the contamination of optical components in a lithographic apparatus, which addresses the problems of the previously used systems as described above.

According to the invention there is provided a lithographic projection apparatus comprising:

an illumination system for supplying a projection beam of electromagnetic radiation;

a first object table for holding a mask;

a second object table for holding a substrate; and

a projection system for imaging an irradiated portion of said mask onto a target portion of said substrate;

characterized in that a space containing at least a part of said illumination system, and/or a space containing at least a part of said projection system contains an inert gas at a pressure of 0.1 to 10 Pa.

The inventors have found that by introducing an inert gas into either or both of the illumination or the projection system, the mean free path of any contaminant particles contained in the system is reduced. This has the effect of suppressing the contamination of any optical components, such as mirrors, located in the illumination and/or projection systems. The contamination of such optical components can be suppressed by a factor of about 10 to 10^3 using this method. Thus, the mirror surfaces are protected and the decrease in their reflectance over time is reduced, thereby increasing their useful lifetime.

The invention also relates to a method of manufacturing a device using a lithographic projection apparatus comprising:

an illumination system for supplying a projection beam of electromagnetic radiation;

a first object table for holding a mask; and

a second object table for holding a substrate; the method comprising the steps of:

providing a mask bearing a pattern to said first object table;

providing a substrate having a radiation-sensitive layer to said second object table;

irradiating portions of the mask with said projection beam; and

imaging irradiated portions of the mask onto target portions of the substrate;

characterized by the step of supplying an inert gas to a space containing at least a part of said illumination system and/or a space containing at least a part of said projection system, wherein the pressure in said space(s) is from 0.1 to 10 Pa.

In a manufacturing process using a lithographic projection apparatus according to the invention a pattern in a mask is imaged onto a substrate which is at least partially covered by a layer of radiation-sensitive material (resist). Prior to this imaging step, the substrate may undergo various procedures, such as priming, resist coating and a soft bake. After exposure, the substrate may be subjected to other procedures, such as a post-exposure

bake (PEB), development, a hard bake and measurement/inspection of the imaged features. This array of procedures is used as a basis to pattern an individual layer of a device, e.g. an IC. Such a patterned layer may then undergo various processes such as etching, ion-implantation (doping), metallization, oxidation, chemo-mechanical polishing, etc., all intended to finish off an individual layer. If several layers are required, then the whole procedure, or a variant thereof, will have to be repeated for each new layer. Eventually, an array of devices (dies) will be present on the substrate (wafer). These devices are then separated from one another by a technique such as dicing or sawing, whence the individual devices can be mounted on a carrier, connected to pins, etc. Further information regarding such processes can be obtained, for example, from the book "Microchip Fabrication: A Practical Guide to Semiconductor Processing", Third Edition, by Peter van Zant, McGraw Hill Publishing Co., 1997, ISBN 0-07-067250-4.

Although specific reference may be made in this text to the use of the apparatus according to the invention in the manufacture of ICs, it should be explicitly understood that such an apparatus has many other possible applications. For example, it may be employed in the manufacture of integrated optical systems, guidance and detection patterns for magnetic domain memories, liquid-crystal display panels, thin-film magnetic heads, etc. The skilled artisan will appreciate that, in the context of such alternative applications, any use of the terms "reticle", "wafer" or "die" in this text should be considered as being replaced by the more general terms "mask", "substrate" and "exposure area", respectively.

In the present document, the invention is described using a reference system of orthogonal X, Y and Z directions and rotation about an axis parallel to the *I* direction is denoted R*i*. Further, unless the context otherwise requires, the term "vertical" (Z) used herein is intended to refer to the direction normal to the substrate or mask surface, rather than implying any particular orientation of the apparatus.

The invention and its attendant advantages will be further described below with reference to exemplary embodiments and the accompanying schematic drawings, wherein:

Figure 1 depicts a lithographic projection apparatus according to the invention;

Figure 2 depicts the illumination system of the invention in more detail; and

Figure 3 depicts the projection system of the invention in more detail.

In the drawings, like parts are identified by like references.

Embodiment 1

Figure 1 schematically depicts a lithographic projection apparatus according to the invention. The apparatus comprises:

- a radiation system LA, IL for supplying a projection beam PB of EUV radiation;
- a first object table (mask table) MT provided with a mask, or first object, holder for holding a mask MA (e.g. a reticle), and connected to first positioning means for accurately positioning the mask with respect to item PL;
- a second object table (substrate or wafer table) WT provided with a substrate, or second object, holder for holding a substrate W (e.g. a resist-coated silicon wafer), and connected to second positioning means for accurately positioning the substrate with respect to item PL;
- a projection system ("lens") PL (e.g. a mirror group) for imaging an irradiated portion of the mask MA onto an exposure area C (die) of a substrate W held in the substrate table WT.

As here depicted, the apparatus is of a reflective type (i.e. has a reflective mask). However, in general, it may also be of a transmissive type, for example.

The radiation system includes a source LA (e.g. an undulator or wiggler provided around the path of an electron beam in a storage ring or synchrotron, a laser-produced plasma source, or a discharge plasma source) which produces a beam of EUV radiation. This beam is passed along various optical components comprised in the illumination system IL — e.g. beam shaping optics, an integrator and a condenser — also included in the radiation system so that the resultant beam PB has a desired shape and intensity distribution in its cross-section.

The beam PB subsequently intercepts the mask MA which is held in a mask holder on a mask table MT. Having passed through the mask MA, the beam PB passes through the lens PL, which focuses the beam PB onto an exposure area C of the substrate W. With the aid of the interferometric displacement measuring means IF, the substrate table WT can be moved accurately by the second positioning means, e.g. so as to position different exposure areas C in the path of the beam PB. Similarly, the first positioning means can be used to accurately position the mask MA with respect to the path of the beam PB. In general, movement of the object tables MT, WT will be realized with the aid of a long-

stroke module (course positioning) and a short-stroke module (fine positioning), which are not explicitly depicted in Figure 1. In the case of a waferstepper (as opposed to a step-and-scan apparatus) the mask table may be connected only to a short-stroke positioning device, to make fine adjustments in mask orientation and position.

The depicted apparatus can be used in two different modes:

1. In step-and-repeat (step) mode, the mask table MT is kept essentially stationary, and an entire mask image is projected in one go (i.e. a single "flash") onto an exposure area C. The substrate table WT is then shifted in the X and/or Y directions so that a different exposure area C can be irradiated by the beam PB;
2. In step-and-scan (scan) mode, essentially the same scenario applies, except that a given exposure area C is not exposed in a single "flash". Instead, the mask table MT is movable in a given direction (the so-called "scan direction", e.g. the Y direction) with a speed v, so that the projection beam PB is caused to scan over a mask image; concurrently, the substrate table WT is moved in the same or opposite direction at a speed $V = Mv$, in which M is the magnification of the lens PL (typically, $M = 1/4$ or $1/5$). In this manner, a relatively large exposure area C can be exposed, without having to compromise on resolution.

Figure 2 shows the illumination system of a specific case of the invention in more detail. In this case, an inert gas is supplied to the entire illumination system to suppress the contamination of optical components in this area. The illumination system IL, which comprises a mirror 3 and optionally various other optical components as described above with reference to Figure 1, is contained within a chamber 2. The chamber is supplied with an inert gas from inert gas supply 5, which may be a pressurized container containing a gaseous or liquid inert gas. The inert gas may be any chemically inert gas such as a noble gas, for example helium, neon, argon, krypton or xenon, or it may be nitrogen or a mixture of any of these gases. The inert gas is preferably one or a mixture of helium, argon or nitrogen, since these gases have a high transparency to radiation in the extreme ultraviolet range. The inert gas is supplied to the chamber 2 via inlet 6, which comprises a valve.

The pressure within the chamber 2 is monitored using pressure sensor means 4. The partial pressure of inert gas in the chamber is adjusted using the valve such that the

total pressure within the chamber remains within the range 0.1 to 10 Pa, preferably 1 to 5 Pa, more preferably 2 to 3 Pa.

Figure 3 shows the projection system of a specific case of the invention in more detail. In this case, an inert gas is supplied to the entire projection system to suppress the contamination of optical components in this area. The projection system PL, which comprises a mirror 8 and optionally various other optical components as described above with reference to Figure 1, is contained within a chamber 7. The chamber is supplied with an inert gas from inert gas supply 10, which may be a pressurized container containing a gaseous or liquid inert gas. The inert gas may be any chemically inert gas such as those described above with reference to Figure 2. The inert gas is supplied to the chamber 7 via inlet 11, which comprises a valve.

The pressure within the chamber 7 is monitored using pressure sensor means 9. The partial pressure of inert gas in the chamber is adjusted using the valve such that the total pressure within the chamber remains within the range 0.1 to 10 Pa, preferably 1 to 5 Pa, more preferably 2 to 3 Pa.

In a further specific case of the present invention, the illumination system and the projection system are contained within two separate chambers and each chamber is supplied with an inert gas as described above with reference to Figures 2 and 3.

The introduction of a low pressure of an inert gas into the chambers 2 and 7 has the effect of decreasing the mean free path of any contaminant particles such as hydrocarbon molecules or water vapor which are present in the chamber. In a chamber evacuated to a pressure of 10^{-1} Pa or less, the mean free path of such particles is larger than the typical dimension of such a chamber. The flux of the particles towards an optical component, such as a mirror, in the chamber is therefore determined by direct molecular bombardment of the component's surface. The molecular flux can be calculated using the following equation:

$$\text{Molecular flux} = \frac{n_{CH_x} v}{4}$$

where n_{CHx} is the contaminant concentration (largely made up of hydrocarbons) and ν is the mean velocity of the contaminant particles.

By introducing an inert gas into the chamber at a pressure of 0.1 to 10 Pa, the mean free path of the contaminant particles is decreased and the flux of the particles towards the optical component is now determined by diffusion. The diffusion flux can be calculated as follows:

$$\text{Diffusion flux} = D\frac{n_{CH_x}}{l}$$

where D, the diffusion coefficient, is determined by $D = \frac{kT\nu}{3\sigma p}$, l is the characteristic size of a contaminant particle, σ is the diffusion cross section, p is the background pressure in the chamber and k is Boltzmann's constant. σ can be calculated using a known diffusion coefficient for Ar-CH_4 mixtures at a given T and p. ν, the mean velocity of the molecules in the mixture can in this case be calculated using:

$$\nu = \sqrt{\frac{8kT}{\pi M}}$$

where M is the mass of a molecule in the mixture.

The degree by which the introduction of inert gas into the chamber suppresses contamination of an optical component can be considered in terms of a suppression factor which is calculated as follows:

$$\text{Suppression factor} = \frac{\text{Molecular flux}}{\text{Diffusion flux}} = \frac{l\nu}{4D} = \frac{3lp\sigma}{4kT}$$

It can be determined from this equation that the suppression of contamination is increased when the contaminant particles are larger or when the background pressure is increased. However, an increased pressure of inert gas in the chamber will result in a decreased transparency to EUV radiation and will therefore decrease the efficiency of the system. Although this effect is less important for gases such as helium, argon and nitrogen, which are highly transparent to EUV radiation, there is still a significant difference in the

transparency of these gases to EUV radiation with an increase in pressure. Thus, the pressure of the inert gas should be kept at or below 10 Pa, advantageously at or below 3 Pa.

Whilst we have described above specific embodiments of the invention it will be appreciated that the invention may be practiced otherwise than described. The description is not intended to limit the invention.

CLAIMS:

1. A lithographic projection apparatus comprising:

an illumination system for supplying a projection beam of electromagnetic radiation;

a first object table for holding a mask;

a second object table for holding a substrate; and

a projection system for imaging an irradiated portion of said mask onto a target portion of said substrate;

characterized in that a space containing at least a part of said illumination system, and/or a space containing at least a part of said projection system contains an inert gas at a pressure of 0.1 to 10 Pa.

2. An apparatus according to claim 1, wherein said illumination system is adapted to produce a projection beam of extreme ultraviolet radiation having a wavelength of less than 50nm.

3. An apparatus according to claim 2, wherein said beam of extreme ultraviolet radiation has a wavelength in the range of from 8 to 20 nm, especially 9 to 16 nm.

4. An apparatus according to any one of the preceding claims, wherein said inert gas is helium, argon or nitrogen, or a mixture thereof.

5. An apparatus according to any one of the preceding claims, wherein the pressure in said space(s) is from 2 to 3 Pa.

6. A method of manufacturing a device using a lithographic projection apparatus comprising:

an illumination system for supplying a projection beam of electromagnetic radiation;

a first object table for holding a mask;

a second object table for holding a substrate; and

a projection system for imaging an irradiated portion of said mask onto a target portion of said substrate; the method comprising the steps of:

providing a mask bearing a pattern to said first object table;

providing a substrate having a radiation-sensitive layer to said second object table;

irradiating portions of the mask with said projection beam; and

imaging irradiated portions of the mask onto target portions of the substrate;

characterized by the step of supplying an inert gas to a space containing at least a part of said illumination system and/or a space containing at least a part of said projection system, wherein the pressure in said space(s) is from 0.1 to 10 Pa.

7. A device manufactured in accordance with the method of claim 6.

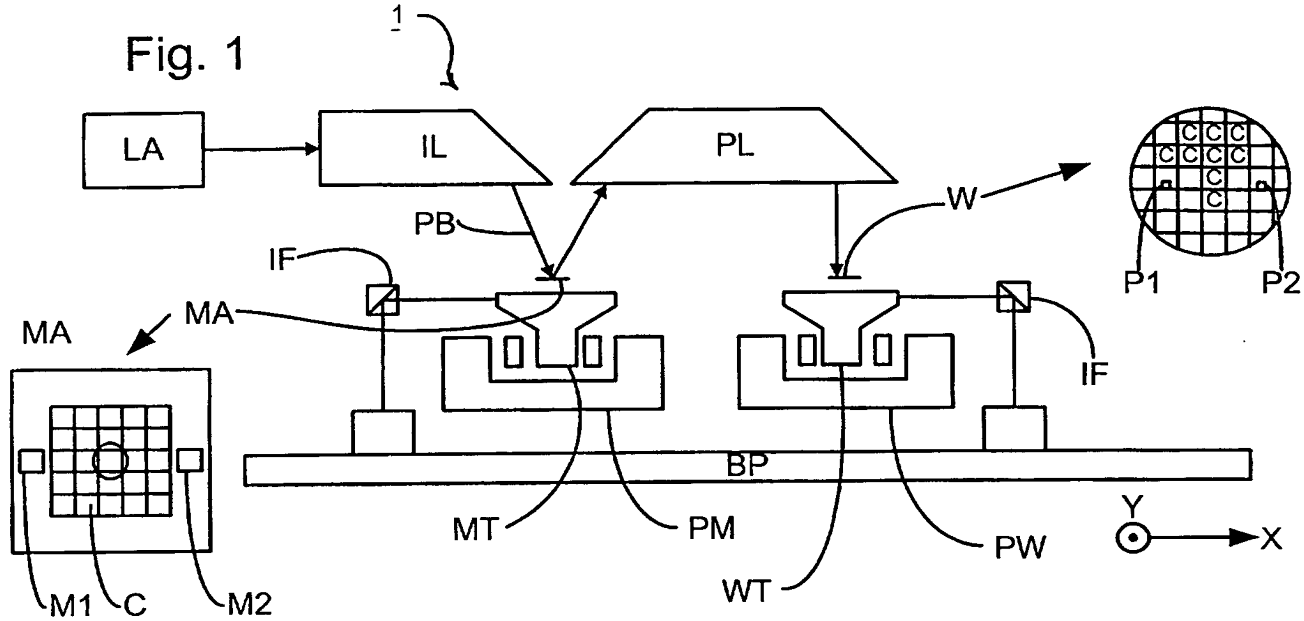
ABSTRACT:

Background Gas Composition for use in Lithographic Projection Apparatus

A lithographic projection apparatus comprising a radiation system for supplying a projection beam of radiation, a mask table for holding a mask, a substrate table for holding a substrate and a projection system for imaging an irradiated portion of the mask onto a target portion of the substrate. Either or both of the illumination system and the projection system is supplied with an inert gas at a pressure of from 0.1 to 10 Pa in order to suppress contamination, for example by hydrocarbon molecules, of any optical components in the system(s).

Fig. 1

Fig. 1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C
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P1
P2
IF
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M1
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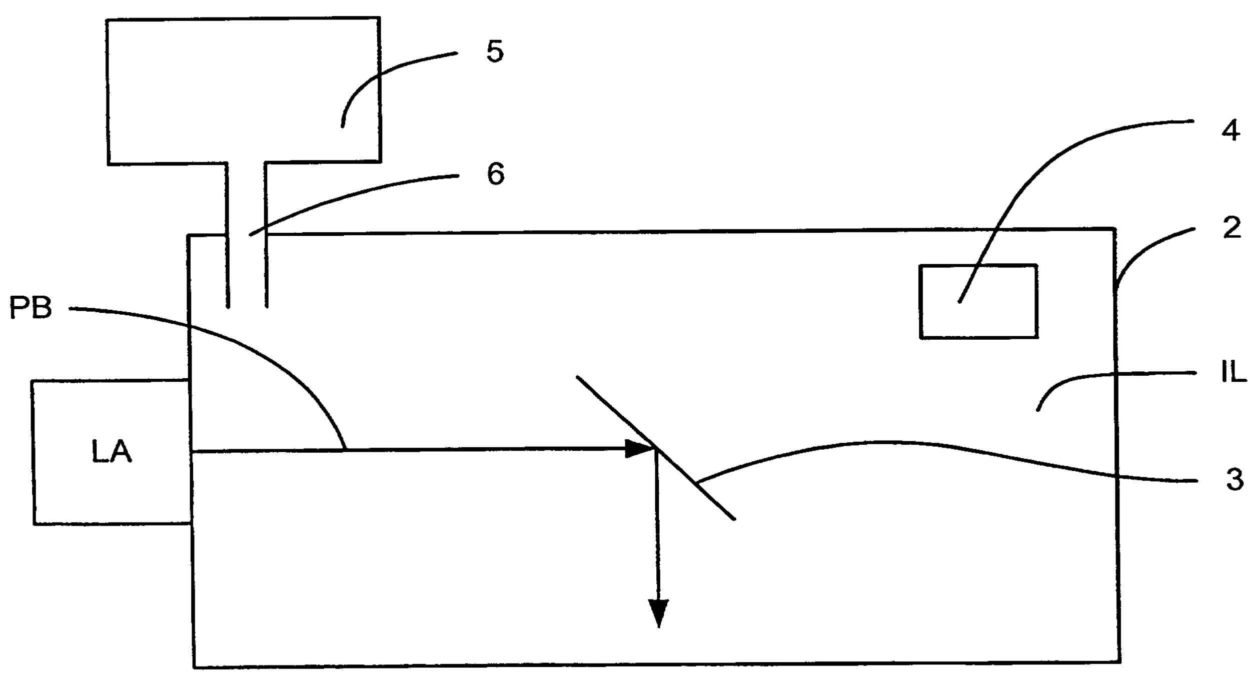
Fig. 2


5
6
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2
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Fig. 3